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Research projects for MSc CE

RaffaLab

Smart and Sustainable Polymeric Products

Chemical Product Technology

Faculty of Science and Engineering

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Smart and Sustainable Polymeric Products

Sustainable acrylic polymers for paints/coatings

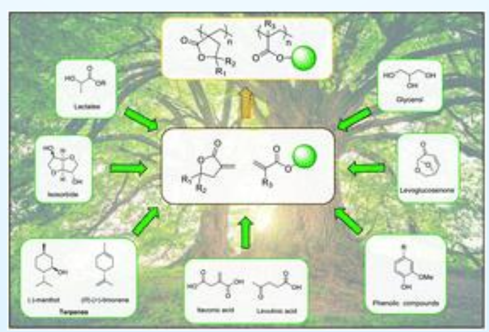
Binders and dispersants for paints & coatings are typically constituted by fossil-based acrylates. Moreover, many coating formulations make use of organic solvent to be able to dissolve these polymeric materials.

Various acrylic monomers can be obtained from chemical transformation of agricultural waste or other bio-based sources*. These can be combined via radical polymerization, to form sustainable acrylic polymers. Additionally, the right combination of monomers allows to obtain amphiphilic water-dispersible precursors, thus avoiding the use of toxic organic solvents.

In this project the synthesis of amphiphilic polymers from bio-based acrylates will be explored. These will be tested as precursors of a new generation of sustainable waterborne paints and coatings.

Project tasks:

- Design and synthesis of bio-based monomers and polymers
- Characterization of polymers (NMR, GPC)
- Preparation and characterization of water dispersions (DLS, rheology)
- Optimization of coating preparation
- Coating characterization (FT-IR, DSC, TGA, hardness, contact angle)



* *Polym. Chem.*, 2020, 11, 7452-7470

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Smart and Sustainable Polymeric Products

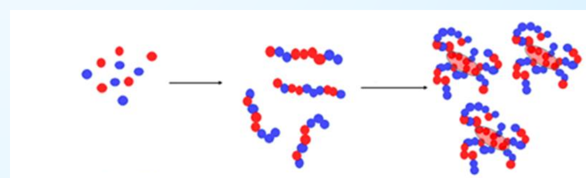
Sustainable emulsifiers/dispersants for personal care or pharmaceutical products

Personal care, pharmaceuticals and other consumer products contain amphiphilic polymers in their formulation, able to form w/o or o/w emulsions. These polymers are typically unsustainable (because produced from fossil-based sources) and non-biodegradable. The latter is a big problem, because these products end up in municipal water streams, increasing pollution.

A potential solution to this problem, is via the design of biodegradable amphiphilic polymers based on renewable sources (such as biopolymers, or bio-based monomers*). This project aims at obtaining sustainable and biodegradable amphiphilic polymers, suitable to potentially replace the current ones.

Project tasks:

- Design and synthesis of bio-based amphiphilic polymers
- Characterization of polymers (NMR, GPC)
- Study of solution properties (surface tension, IFT, rheology) and emulsification / emulsion stability
- Study of biodegradability (BOD test)



** ACS Appl. Polym. Mater., 2020, 2, 12, 5705–5715*
ACS Sustain. Chem. Eng., 2022, 10, 14806–14816
React. Funct. Polym., 2022, 172, 105204

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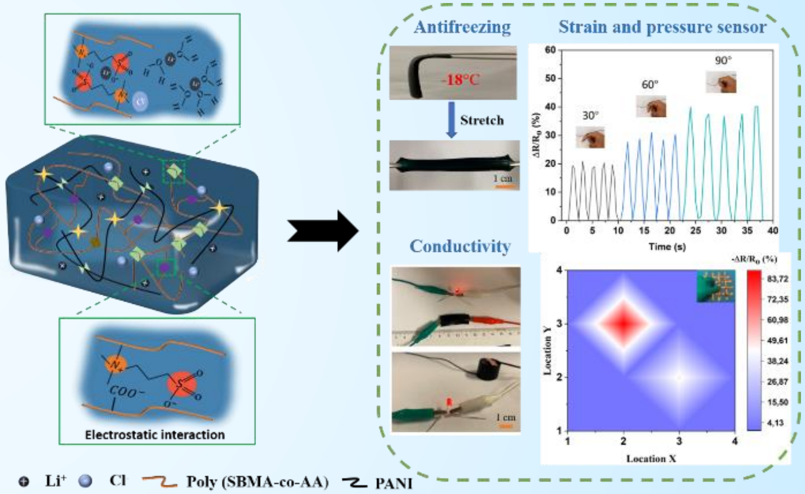
Smart and Sustainable Polymeric Products

Smart hydrogels for motion sensing

In recent years, tremendous efforts have been devoted to developing soft electronic materials to address the growing global demand for flexible electronics, aimed at improving healthcare monitoring and human–machine interactions. Conductive hydrogels have emerged as promising materials for strain/movement sensors, due to their biological tissue-like texture, high water content, high flexibility and stable conductivity.
However, they also suffer of several drawbacks, such as limited temperature operating window, ease to crack, and non-usability in underwater environment.

Various strategies have been developed to overcome these known problems*, but more remains to be done.

In this project, new formulation of soft materials will be designed and tested to improve properties of strain sensors, endowing them with self-healing properties, and resistance to water and/or low temperatures.



Project tasks:

- Design and synthesis of polymer-based hydro- or organogels
- Testing of mechanical properties
- Conductivity / strain sensor tests

* Eur. Polym. J., 2023, 199, 112484

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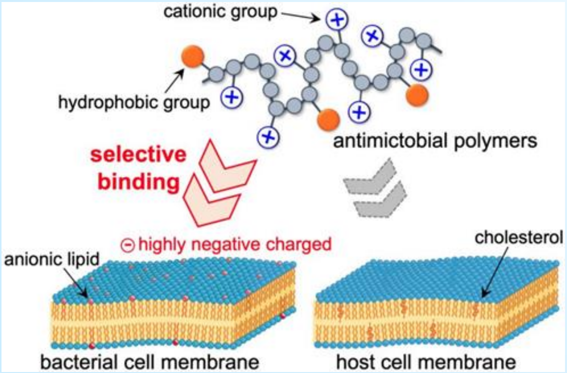
Smart and Sustainable Polymeric Products

Biobased antimicrobial polymers for biomedical applications

Antibiotic resistance has become an urgent issue in the global healthcare and agriculture fields. Antibacterial polymers have been developed as a mimicry version of host defense peptides (a part of the natural immune system of multicellular organisms)*. By utilizing advanced polymerization techniques, polymer structures can be easily manipulated in a well-defined and controlled manner, enabling precise evaluation of structure-activity relationships. Therefore, this project aims to synthesize novel polymeric agents with high antibacterial activity and low toxicity to host cells, by utilizing bio-based chemicals as raw materials and to investigate the impact of different amino acid side chains (aliphatic/aromatic, positively charged) on the antibacterial activity of the synthesized amphiphilic antibacterial polymers.



Project tasks:

- Design and synthesis of antibacterial polymers
- Polymer characterization (NMR, GPC, …)
- Solution properties
- Toxicity and antibacterial properties evaluation (at UMCG)

* Biomater. Sci., 2021,9, 2758-2767

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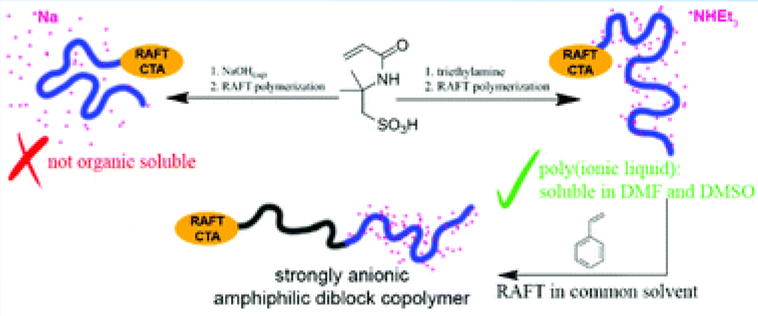
Novel strategies for amphiphilic polyelectrolytes synthesis and solution properties

Polyelectrolytes are well-established polymeric materials, possessing high charge density along the chain. They have been applied in biomaterials, hydrogels, colloid stabilizers, solid electrolytes for fuel cells, and enhanced oil recovery. These applications can be potentially greatly expanded by producing polyelectrolyte-containing well-defined block copolymers. Such materials are generally made using a range of controlled radical polymerization methods, such as ATRP or RAFT.

However, the introduction of hydrophobic monomers in strong polyelectrolytes to produce amphiphilic block copolymers is challenging, due to the difficulty to find suitable solvents for both blocks. PISA (polymer-induced self-assembly) can be used directly in water, but it does not allow to produce well-controlled structures. The use of hydrophobic precursors, that can be further chemically modified to make them charged, is also possible, but it requires multiple reaction steps.



We have recently developed an easy method based on converting a charged monomer (AMPS) to a ionic liquid by neutralization with a tertiary amine*, allowing to introduce a polystyrene block.

This project aims at expanding this procedure to other monomers, to make it a general strategy for the synthesis of amphiphilic block polyelectrolytes. In this respect, it does not look at a specific application, but it aims at obtaining a paradigm shift in polymer synthesis.

* Polym. Chem., 2021,12, 5505-5517

Miscellaneous topics/collaborations

- Amphiphilic polymers and/or nanoparticles for enhanced oil recovery
- Modified polyolefins for improved properties (SABIC)
- Biobased polyester-amides for biodegradable coatings (COSUN/Covestro)
- Water swelling rubbers for constructions (Volteco)